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Report on how IBSE is implemented and assessed in participating countries

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A. Background to this report

This report is a deliverable of ***Work Package 2 (WP2)*** of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). It meets the requirements of the ***Deliverable 2.1*** by presenting an overview of how inquiry-based science education (IBSE) is implemented and assessed in the beneficiary countries of ESTABLISH. (See Table 1 below for beneficiary list).

The purpose of WP 2, among other tasks, is to examine the extent to which inquiry-based science education (IBSE) is currently implemented in the second level (12-18 years olds) science curricula in each ESTABLISH country and in national assessment criteria. It also aims to identify the potential barriers for the implementation of IBSE in classrooms in the beneficiary countries of ESTABLISH.

The findings are informed by the opinion of the contributors to this report and do not necessarily reflect national policy. The WP2 contact points in each country were Rory Geoghegan (AGES), Ewa Kedzierska (UvA), Nicos Valanides (UCY), Christina Ottander (UmU), Malgorzata Krzeczkowska (JU), Ewa Odrowaz, (JU), Zdeněk Drozd (CUNI), Annalise Duca (AL), Dušan Šveda (UPJS), Stefanie Herzog (COUO), Miia Rannikmae (UTARTU), Giovanni Tarantino (UNIPA), Maria Sandström (MaH) and Martin Lindner (IPN). The report was compiled by Jim Salisbury (AGES), Rory Geoghegan (AGES), Anna Gethings (AGES), Lorraine McCormack (DCU), Odilla Finlayson (DCU), Sarah Brady (DCU) and Eilish McLoughlin (DCU) and was approved for submission by the ESTABLISH Project Steering Committee.

This report focuses on the description of inquiry-based approaches to science education in national curricula and their assessment. It is compiled based on the written responses of the WP2 contact points in each country. Related issues were also discussed at the second ESTABLISH General Assembly meeting and with individual respondents when necessary.

This document, published in April 2011, has been produced within the scope of the ESTABLISH Project. The utilisation and release of this document is subject to the conditions of the contract within the Seventh Framework Programme, project reference FP7-SIS-2009-1-244749.

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B. The ESTABLISH consortium

Table 1: List of beneficiary organisations in the FP7 ESTABLISH project 244749, 2010-2013.

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UvA	UNIVERSITEIT VAN AMSTERDAM	The Netherlands	NL
UCY	UNIVERSITY OF CYPRUS	Cyprus	CY
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
COUO	CARL VON OSSIETZKY UNIVERSITAET OLDENBURG	Germany	DE
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE

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1. Summary

This report presents an overview of the extent to which inquiry-based approaches are currently implemented/conceptualised in second level (12-18 year olds) science curricula and in the national assessment criteria of those countries participating in the ESTABLISH project (Table 1).

For the purposes of the ESTABLISH project, the consortium have adopted the definition of inquiry presented by Linn, Davis and Bell[1] namely,

'the *intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments.'*

WP2 contact points were asked to indicate which of these nine elements of inquiry are mentioned in respective national curriculum or assessment documentation. Responses indicated that, in every country, some elements of inquiry are explicitly or implicitly stated in curriculum and in national assessment criteria. Many new national curricula in the ESTABLISH beneficiary countries now include additional elements of inquiry. Additionally, in six of the eleven participating countries all nine elements of inquiry are stated in the documentation.

The elements of inquiry identified do not always reflect those elements of teaching and learning that are actually assessed. Elements, such as, 'researching conjectures,' 'constructing models,' and 'debating with peers,' are poorly reflected in assessment. There is a need to further examine the correlations between the curriculum objectives in terms of inquiry and their assessment. This will be undertaken as part of report Deliverable 2.2 of the ESTABLISH project.

It is also clear that while inquiry-based approaches to science education (IBSE) are included in all pre-service teacher education programmes, the opportunities available to the in-service teachers seem to diverse across the participating countries, ranging from national programmes to local initiatives.

An overview of projects funded through the EU Science and Society Calls in 2008 and 2009 (activity 5.2.2.1) shows that there are beneficiaries from 29 countries engaged in FP7 projects to address the use of IBSE in classrooms and in teacher education. This indicates that there is widespread involvement of IBSE in teacher education programmes across Europe.

Additionally, although each of the countries participating in ESTABLISH have implemented initiatives to promote IBSE; the impact of these programmes on the widespread use of IBSE is difficult to determine.

April 2011

[1] Linn, M. C., Davis E.A., & Bell, P. (2004). Internet Environments for Science Education. Mahwah, NJ.: Lawrence Erlbaum Associates

2. Introduction

Inquiry-based teaching methodologies are designed to engage students in science and mathematics by increasing their interest in science and also by stimulating teacher motivation[2]. However, widespread implementation of such a methodology will only occur with inclusion and participation of all partners in education, both formal and informal. The ESTABLISH project aims to encourage and promote the more widespread use of inquiry-based science teaching techniques in second level schools through ***appropriate teacher education, creation of authentic learning environments and actions to bridge the gap between the science education research community, science teachers, students, parents, local industry as well as policy makers in order to facilitate the uptake of inquiry-based science teaching***.

The rationale for this project lies in creating authentic learning environments for science by bringing together and involving all stakeholders who can make change possible. Teachers themselves are active partners in this project, both as developers, researchers and agents for change. In this way, real change in classroom practice can be achieved.

While IBSE has been recently encouraged by the European Commission[2], individual countries have adopted this approach (or variants of it) to different degrees over the past decade. This report presents an overview of the extent to which inquiry-based science education (IBSE) is currently practised in the second level schools (12-18 years olds) of the beneficiary countries in the ESTABLISH project. The information provided in this report is based on responses received from WP2 contact points as identified in Work Package 2 of the ESTABLISH project.

This report presents an overview of the:

1. Initiatives that have been implemented to support the use of IBSE;
2. Elements of inquiry, as defined by ESTABLISH project, that are explicitly presented within the national curricula;
3. Elements of IBSE, as defined by ESTABLISH project, that are explicitly presented in the national assessment criteria;
4. Level of teachers' use of IBSE activities in their classrooms and the proportion of their time devoted to these activities;
5. Level of teacher preparation (both pre-service and in-service) for IBSE;
6. Issues that act as barriers for teachers in implementing IBSE in the classroom;
7. Initiatives for the promotion of IBSE that have been undertaken.

[2] European Commission (EC), & High Level Group on Science Education. (2007). Science Education NOW: A Renewed Pedagogy for the Future of Europe (EUR 22845). Brussels: DG Research.

3. Inquiry-Based Science Education (IBSE)

The recent trend across the EU towards competence-based teaching and learning, and a learning outcome approach[3] has resulted in significant changes occurring in second-level school curricula in mathematics and science. These subjects are being treated in more engaging cross-curricular ways with greater emphasis being placed on developing skills and positive attitudes alongside knowledge, and with increased use of "real-life" applications to provide appealing learning contexts. Methodologies, such as inquiry-based science education (IBSE)[2,4] have been highlighted to increase student motivation and engagement in science at primary and second level and also to stimulate teacher motivation.

Since 2008, several FP7 projects have been initiated (activity 5.2.2.1) to encourage and support teachers to use IBSE in their classrooms. These projects each have a unique emphasis: such as the development of IBSE resources and materials (PRIMAS[5], 2009-2012); provision of authentic materials informed by industry (ESTABLISH[6], 2010-2013) and development of suitable teacher education workshops (S-TEAM 2009-2012[7], Fibonacci[8], 2010-2013). Collectively these projects (S-TEAM, Fibonacci, PRIMAS and ESTABLISH) focus on the education of teachers in implementing IBSE in their classrooms, and the promotion of the widespread use of IBSE in teaching and learning of science and mathematics.

In total, 29 countries in Europe (Table 2) have organisations that are involved in these four projects, with many countries involved in more than one of these projects. As a result of this, some significant benefits have manifested:

- In each of these 29 countries there are now groups of teachers educated in the practice of IBSE, and are potentially actively practicing IBSE in their own classrooms;
- IBSE materials and resources have been developed for use in teacher education and these are being shared through a central European platform, Scientix[9],
- Several reports on specific aspects relevant to IBSE teacher education are available, which inform the on-going work of existing and emerging projects in IBSE. (For example, a preliminary report on IBST policy is available from S-Team project[7] which has informed the basis of this work).

[3] Commission of the European Communities (CEC). (2009). Key competences for a changing world: Progress towards the Lisbon objectives in Education and Training (Commission Staff working document SEC(2009) 1598 FIN). Brussels: Commission of the European Communities.

[4] Web-base Inquiry Science Environment (WISE). (1998). Available: http://wise.berkeley.edu/.

[5] Available: http://www.primas-project.eu

[6] Available: http://www.establish-fp7.eu

[7] Available: http://www.ntnu.no/s-team

[8] Available: http://www.fibonacci-project.eu

[9] Available: http://www.scientix.eu

Table 2: List of countries involved in FP7 (SiS - Area 5.2.2.1) projects in IBSE.

Country (total no. of partners)	**S-TEAM (25)**	**ESTABLISH (14)**	**Fibonacci (25)**	**PRIMAS (14)**
Austria			√	
Belgium			√	
Bulgaria			√	
Cyprus	√	√		√
Czech Republic	√	√		
Denmark	√		√	√
Estonia	√	√	√	
Finland	√		√	
France	√		√	
Germany	√	√	√	√
Greece			√	
Hungary				√
Ireland		√	√	
Italy		√	√	
Lithuania	√			
Luxembourg			√	
Malta		√		√
Netherlands		√		√
Norway	√			√
Poland		√	√	
Portugal			√	
Romania			√	√
Serbia			√	
Slovakia		√	√	√
Slovenia			√	
Spain	√		√	√
Sweden	√	√		
Switzerland			√	√
United Kingdom	√		√	√

4. IBSE in National Curricula and Assessment

Understanding the extent to which IBSE is currently practised in the ESTABLISH beneficiary countries is key to providing a context that will inform the future activities of ESTABLISH.

Arising from the varied interpretations of the term 'inquiry-based approaches', the ESTABLISH consortium have adopted an agreed definition of inquiry as presented by Linn, Davis and Bell[1] with nine constituent elements, namely, '*diagnosing problems*', '*critiquing experiments'*, '*distinguishing alternatives'*, '*planning investigations'*, '*researching conjectures'*, '*searching for information'*, '*constructing models*', '*debating with peers'*, and '*forming coherent arguments'*. Each WP2 contact point was asked to indicate which of these elements of inquiry are included in their national science curricula and assessment criteria.

A. Role of IBSE in National Curricula

Table 3 presents information provided by the WP2 contact point on the extent to which the elements of IBSE is either explicitly stated or implied in national curriculum across the ESTABLISH beneficiary countries. This table indicates that all nine elements of inquiry are present in the curricula of six of the eleven ESTABLISH beneficiary countries (Czech Republic, Germany, Estonia, Netherlands Slovakia and Sweden), while Poland includes eight of these elements. However, all the remaining countries include at least some (three to six) of these elements, with the minimum number of elements being three (Malta). Of the nine elements presented, the most commonly included in the national curricula are "Planning investigations" (11 of the countries), "Critiquing experiments" and "Searching for information" (10 of the countries) with "Constructing models" having the lowest occurrence and is not listed by four of the countries. It should be noted here that, while many curricula use inquiry based terms in documentation, it is often not clear to what extent this leads to inquiry based classroom practice. This link between curriculum statements and classroom practice will be explored in further ESTABLISH reports.

Table 3: Extent to elements of inquiry are explicitly stated or implied in National Curricula across ESTABLISH beneficiary countries.

Elements of Inquiry	CY	CZ	DE	EE	IE	IT	MT	NL	PL	SK	SE
Diagnosing problems		√	√	√		√	√	√	√	√	√
Critiquing experiments	√	√	√	√	√		√	√	√	√	√
Distinguishing alternatives		√	√	√		√		√	√	√	√
Planning investigations	√	√	√	√	√	√	√	√	√	√	√
Researching conjectures		√	√	√		√		√	√	√	√
Searching for information	√	√	√	√	√	√		√	√	√	√
Constructing models		√	√	√		√		√		√	√
Debating with peers	√	√	√	√	√			√	√	√	√
Forming coherent arguments		√	√	√	√			√	√	√	√

Identification of each country is: CY- Cyprus, CZ-Czech Republic, DE-Germany, EE-Estonia, IE- Ireland, IT- Italy, MT- Malta, NL-Netherlands, PL- Poland, SK-Slovakia and SE-Sweden.

B. Role of IBSE in National Assessment

Table 4 provides a summary of responses from the WP2 contact points on the elements of IBSE that are explicitly stated or implied in their national assessment criteria. The information presented indicates that in three of the countries (Czech Republic, Estonia and Netherlands) all nine elements of inquiry are also present in the national assessment criteria, with a total of six of the elements included in a further two countries (Poland and Italy). However, all countries include some of the elements in assessment (Slovakia have 4 elements, with Germany, Cyrpus, Malta, Sweden all have 3 elements) and the minimum number being assessed is two elements (Ireland). Of the nine elements considered the most commonly assessed element was "Planning investigations" (10 of the countries) with a further five of the elements (Diagnosing problems, Critiquing experiments, Distinguishing alternatives, Searching for information, Forming coherent arguments) assessed in seven of these eleven countries. The assessment of "Debating with peers" had the lowest occurrence and is only listed in the assessment criteria of four of these countries.

Table 4: Extent to which IBSE is explicitly stated or implied in National Assessment criteria across ESTABLISH beneficiary countries.

Elements of Inquiry	CY	CZ	DE	EE	IE*	IT	MT	NL	PL	SK	SE
Diagnosing problems		√	√	√		√	√	√	√	0	0
Critiquing experiments	√	√	0	√	0		√	√	0	0	√
Distinguishing alternatives		√	√	√		√		√	√	√	0
Planning investigations	√	√	√	√	√	√	√	√	√	0	√
Researching conjectures		√	0	√		√		√	√	0	0
Searching for information	√	√	0	√	0	√		√	√	√	0
Constructing models		√	0	√		√		√		√	0
Debating with peers	0	√	0	√	0			√	0	0	0
Forming coherent arguments		√	0	√	√			√	√	√	√

Identification of each country is: CY- Cyprus, CZ-Czech Republic, DE-Germany, EE-Estonia, IE- Ireland, IT- Italy, MT- Malta, NL-Netherlands, PL- Poland, SK-Slovakia and SE-Sweden.

'0' indicates that while this element is included in the curriculum, it is not assessed directly as an IBSE method.

**For Ireland the information provided in Table 4 represents the junior cycle science subject (12-15 years). There are no elements of inquiry assessed at senior cycle (15-18 years) for any of the science disciplines in Ireland.*

In comparing Table 3 and Table 4, a number of tentative conclusions can be drawn. In only three of the countries (Czech Republic, Estonia and Netherlands) are all nine elements of inquiry included, both in the curriculum and in the assessment criteria. It is clear that there is a mismatch between elements of inquiry that are included in the curricula and the elements that are stated in the assessment criteria. Those elements that are included in the curriculum but not in the assessment criteria for a given country are indicated by '0' in Table 4.

It must be noted here that the aforementioned information is used to present a general overview of the level of inquiry in the curricula and assessment in the beneficiary countries. While many curriculum and syllabi documents contain statements and phrases that, on the surface, seem to support an IBSE approach, these references are often aspirational and are not necessarily supported by clear assessment statements. Therefore, a subsequent ESTABLISH report (Deliverable 2.2) will present on the findings of the analysis and comparison of specific examples of statements from curricula and how these statements match the assessment criteria.

5. Initiatives to Support IBSE

A range of initiatives to promote the use of inquiry-based approaches in the classroom that have been supported by national, regional, local and EU funded projects are presented in Table 5. Some of these programmes are associated with development of national curricula, while others are as a result of a more local/regional impetus, with the drivers behind these initiatives ranging from policy and government to schools and industry. This listing is not intended to be a comprehensive list or a review of IBSE initiatives but as an indication of relevant projects and as a guide for ESTABLISH beneficiaries and others involved in IBSE.

Table 5: Initiatives to support the use of inquiry-based approaches in ESTABLISH beneficiary countries.

Country	Description of Initiative	Year(s)	Reference
Cyprus	National Curriculum in IBSE is under development	2011-	
Czech Republic	Heureka Project in Physics curriculum and teacher education.	1991	http://kdf.mff.cuni.cz/heureka/en/
	Středoškolská odborná činnost - voluntary national student competition.	1977-1978	http://www.soc.cz/
	National Framework Educational Programmes at end of high school statement of key skills gained includes problem solving, planning investigation, critical discussion).	2007	http:/planipolis.iiep.unesco.org
Germany	SINUS-Programme	2003-2004	http://sinus-transfer.uni-bayreuth.de/home.html
	CHiK (Chemistry in Kontext)	1997-	http://www.chik.de/
	BiK - Biology in Context	2005-	www.bik.ipn.uni-kiel.de/
	Piko - Physics in Context	2004-	www.uni-kiel.de/piko
	NaWi Kontext and NaWi 5/6	2008	http://www.nawi-kontext.de/ www.nawi5-6.de
	FP6 PARSEL Project	2006-2009	www.parsel.eu
	Jahr der Naturwissenschaften 2010 (Year of the natural sciences)	2010	www.naturwissenschaften2010.schleswig-holstein.de
Estonia	National Curriculum in IBSE	2010-	http://www.kutsekoda.ee
Ireland	Investigative Approach to Science at Lower Secondary level	2003-	www.ncca.ie
Italy	Piano Insegnare Scienze Sperimentali – Nationally funded project	2007-2011	http://www.lfns.it/PianoISS/
	Progetto Lauree Scientifiche– Nationally funded project	2005-2011	http://www.progettolaureescientifiche.eu

Country	Description of Initiative	Year(s)	Reference
Malta	National Curriculum in IBSE is under development	2011-	http://www.curriculum.gov.mt/
Netherlands	National curriculum for Physics, Chemistry and Biology to address IBSE amongst other aspects.	2010-	
Poland	New National Curriculum in science includes some elements of IBSE. National Curriculum reform oriented on inquiry, students competencies, active learning, projects.	2009-	http://www.reformprogramowa.men.gov.pl/images/Podstawa_programowa/men_tom_5.pdf
Slovakia	National Curriculum reform oriented on students competencies, active learning, learning by doing, project oriented activities	2009-	http://www.statpedu.sk http://www.nucem.sk/en/
	FAST project and active learning approach into basic school curriculum, textbooks and study plans.	2006	http://www.minedu.sk
Sweden	FP7 Project CoReflect (Digital support for Inquiry, Collaboration, and Reflection on Socio-Scientific Debates))	2008-2011	http://www.coreflect.org/nqcontent.cfm?a_id=3866&tt=coreflect&lang=en
	National subject tests in biology, chemistry and physics are introduced for ages 15-16 year old.	2010-	http://www.skolverket.se/sb/d/2916/a/16416 http://www8.umu.se/edmeas/np/amnesprov.html
	Tekniкspanarna	2008-	http://www.teknikspanarna.se/

It is clear that many countries have recognised the value of pursuing IBSE initiatives and some are explicitly supporting IBSE approaches in new curricula and assessment strategies and further information can be obtained from the websites of these initiatives.

6. Practice of IBSE in the Classroom

As outlined in the previous sections, it is clear that elements of IBSE are stated (or implied) in the national curricula of all countries and that some elements of inquiry are also included in the assessment strategies. It is also clear that, on a national level, many initiatives to support IBSE have already taken place and there are many initiatives currently under way. This raises the question as to the proportion of teachers that are actively practicing IBSE in their classrooms, and the proportion of time that they spend on IBSE related activities. Each of the WP2 contact points were asked to estimate the proportion of science teachers in their country that were actively implementing IBSE in their classrooms and the proportion of teaching time devoted to these activities. This information is necessarily based on the personal opinion of the WP2 contact point in each of the ESTABLISH beneficiary countries. The data is compiled in Table 6 and is presented for lower second level, i.e. 12-15yrs, and upper second level, i.e. 15-18yrs.

Table 6: Estimate of the proportion of teachers involved in IBSE activities and the proportion of teaching time devoted to IBSE activities in the classroom

Country	Students Aged 12-15 years		Students Aged 15-18 years	
	Teachers*	Time**	Teachers*	Time**
Cyprus	A	C	A	B
Czech Republic	C	C	C	C
Germany	C	C	C	C
Estonia	C	C	C	C
Ireland	C	C	-	-
Italy	C	C	C	C
Malta	C	C	C	C
Netherlands	B	B	B	C
Poland	C	C	C	C
Slovakia	C	C	C	C
Sweden	A	C	A	C

**In the Teachers column: 'A' indicates most of the teachers; 'B'- approx half of the teachers; 'C'- approx quarter of the teachers; 'D' - none of the teachers.*

*** In the Time column: 'A' indicates most of the time; 'B' -approx half of the time; 'C' - approx quarter of the time; 'D' -none of the time.*

The data presented in Table 6 indicates the following points:

- Most of the teachers in Cyprus are actively using IBSE in their classrooms for about a quarter of the total time devoted to teaching science at lower second level and about half of the time at upper secondary level.
- It is interesting to note that there is more time spent on IBSE activities at the upper second level than at the lower second level in Cyprus, although this is true only for students specializing in science topics.
- This is in contrast to Ireland, where there appears to be no IBSE activity at upper second level. From Tables 3 and 4, in Cyprus, four elements of IBSE were identified as present in the curriculum and three of these are included in the assessment. Additionally, a new national curriculum is under development in Cyprus.
- In Sweden, most of the teachers follow IBSE approaches, but only for about a quarter of the time devoted to science teaching. In Sweden, all elements of IBSE were identified as present in the curricula, but only three of them were stated in the assessment criteria (see Table 3 and Table 4).
- In Poland, a quarter of the teachers are involved in IBSE and about quarter of their time, at both lower and upper second level, is spent on IBSE activities. In Poland, most elements of inquiry are included in the curriculum and are also included in assessment criteria (see Table 3 and Table 4).
- In many of the other countries (Germany, Estonia, Ireland, Italy and Slovakia) it is estimated that approximately a quarter of the teachers are involved in IBSE activities and for approximately a quarter of the time devoted to science teaching. However, there seems to be no correlation between the elements of IBSE present in the curricula and those elements included in the assessment criteria in these countries (see Table 3 and Table 4).

7. Teacher Preparation in IBSE

The WP2 contact points in the ESTABLISH beneficiary countries provided information on the extent to which there is provision of pre-service and in-service teacher education in inquiry based approaches in their countries and this information is outlined in Table 7.

Table 7: Opportunities for teacher education in IBSE

Country	Pre-service	In-service	Details of in-service teacher education e.g. provided at National/Local/project level
Cyprus	√		None
Czech Republic	√	√	None nationally, some locally supported initiatives
Germany	√	√	Provided nationally to all teachers, since 1970s
Estonia	√	√	Provided nationally to all teachers, since 2001
Ireland	√		None
Italy	√	√	Provided nationally to all teachers since 2000
Malta	√		None
Netherlands	√	√	Provided nationally to all teachers, since 1970s
Poland	√	√	Provided nationally to all teachers, since 1970s, also some locally supported initiatives
Slovakia	√	√	None provided nationally; all locally supported and organised activities.
Sweden	√		During 1980-90 in-service activities

This data indicates that:

- IBSE is included in pre-service teacher education programmes in all of the ESTABLISH beneficiary countries. In contrast, there are varied opportunities for in-service teacher education.
- Of the eleven countries represented in the ESTABLISH project, five countries (Germany, Estonia, Italy, Netherlands, and Poland) implement national IBSE related teacher education programmes for in-service teachers, some of which began as early as the 1970s.
- Three of the countries (Cyprus, Ireland and Malta) do not have official provision of in-service teacher education in IBSE.
- The provision of teacher education in Czech Republic, Slovakia and Sweden occurs through locally supported initiatives rather than on a national basis.

It is interesting to note that in Czech Republic, Estonia and the Netherlands, all elements of inquiry were included in their curricula (see Table 3) and in their national assessment criteria (see Table 4) and that these countries also have a national or locally based in-service teacher education provision.

8. Barriers to Implementing IBSE methods

The WP2 contact points in the ESTABLISH beneficiary countries were asked to suggest, in their opinion, the factors that prevent teachers from implementing IBSE in the classroom. The issues presented. The main issues identified as inhibiting factors were similar for all countries and include:

- **Time** (due to over-loaded curriculum),
- **Lack of resources** (which includes materials, equipment and/or laboratory assistance),
- **Lack of in-service teacher education**
- **Lack of alignment between assessment and curriculum objectives**.

It was also reported that teachers consider inquiry-based approaches as an 'add–on' to their teaching, which would demand more time, rather than viewing it as an integrated part of their teaching strategy.

Some countries have introduced special measures to tackle these issues, some of which are 'once-off' initiatives with clearly defined objectives, while other countries have adopted a broader approach with more formal programmes. For example, in Germany, the Leibniz Institute for Science and Mathematics Education (IPN) and the Institute for Quality Development of Schools in Schleswig-Holstein (IQSH), provide resources and teaching materials which are also available online such as, SINUS and Chemie in Kontext. Support is also given by the State Ministry in Germany to promote the use of inquiry-based approaches in the form of reduced workload for teachers. In Ireland and Estonia, project-based investments for equipment (such as, data-logging devices, Vernier instruments) have been provided together with teacher education to support the use of this equipment in classrooms/laboratories for IBSE activities, or to support student investigations. Estonia also received financial support for in-service teacher education as part of the PARSEL EU-funded project. In Poland, initiatives have been driven by the Ministry for Education to facilitate curriculum changes (reforms in 1999 and in 2009) through active learning, Problem Based Learning (PBL), and other projects[10]. Other initiatives were also noted, for example, student-centred projects to encourage IBSE were funded by a variety of sources, including government and industry.

In summary it is evident, that in every country, there are initiatives and activities, both national and local, to address the issue of student engagement in science and IBSE. Nevertheless, it appears that barriers to classroom implementation of IBSE (as identified above) still exist.

[10] Mikina A., Zając B. Metoda projektów w gimnazjum. Poradnik dla nauczycieli i dyrektorów gimnazjów; Strzemieczny J., Jak zorganizować i prowadzić gimnazjalne projekty edukacyjne. Poradnik dla dyrektorów, szkolnych organizatorów i nauczycieli opiekunów

9. Conclusions

Based on the definition of inquiry as stated by Linn, Davis and Bell[1], nine elements of inquiry were identified, i.e., '*diagnosing problems*', '*critiquing experiments'*, '*distinguishing alternatives'*, '*planning investigations'*, '*researching conjectures'*, '*searching for information'*, '*constructing models*', '*debating with peers'*, and '*forming coherent arguments'*.

In each country, most of these elements are stated explicitly or implicitly within the national curricula, and, in six countries, all elements are present. When compared with the assessment criteria for these elements, only four countries present alignment between the curricula and assessment of IBSE elements. The element of '*constructing models'* was the least evident in curricula across all countries, while '*researching conjectures'*, '*constructing models*' and '*debating with peers'* were the least evident in the assessment statements.

In many countries, it is estimated that about a quarter of science teachers devote a quarter of their time to IBSE activities, both at lower and upper second level. Sweden and Cyprus are exceptions, where it is indicated that all teachers are involved for a quarter of their time (or half of their time in the case of Cyprus at upper second level) in IBSE. Further correlations between classroom practice, curriculum objectives and assessment strategies will be examined in more detail and presented in a future ESTABLISH report.

All of the countries involved in the ESTABLISH project have implemented many initiatives to promote IBSE; and some have recently revised their national curricula to include IBSE. However, despite the proliferation of these initiatives, the impact of these programmes is not yet apparent.

It can also be concluded that, while IBSE methodology is included in all pre-service teacher education programmes, this is not the case for in-service teachers. The opportunities available for in-service teachers are diverse over the participating countries, with almost half of the countries having no national IBSE related in-service teacher education programmes in place.

The use of IBSE appears to demand significant change in classroom practice. The processes and skills necessary to conduct IBSE oriented sessions are non-traditional and are perceived to be demanding of classroom time and resources. It seems self evident that ***teacher education***, ***curriculum content*** and ***assessment criteria*** are the primary drivers of change in classroom practice. However, they are not the only ones and ESTABLISH Deliverable 2.2, will present a report on the key forces for driving classroom change, which will consider the full range of forces and obstacles relating to such change. It will also take cognisance of reports from the other relevant projects. In doing so, it will develop on the insights gained from this report on curriculum, assessment and teacher education and identify the interrelationships between these factors that drive change in classroom practice.